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ABSTRACT

Three experiments were conducted to test the effectiveness of programed learning. The first compared the use of a programed text and a teaching machine with a television plus conventional lecture presentation in a DC Electricity course. The second experiment tested the same techniques in an AC Electricity course. The third experiment compared methods of homework preparation to determine if regular homework assignments or programed text homework was more effective in learning calculus for electronics. In DC and AC Electricity courses, there was no significant difference in the performance of subject groups on final unit examinations. The group using a programed text for homework was compared on four examinations with a group using conventional homework techniques. The programed group was significantly superior. In all experiments the programed techniques appeared less affected by ability levels and took less learner time. The report includes samples of the programed materials used. (KB)

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Technical Report: NAVTRADEVCEN 1000-1

A STUDY IN THE APPLICATIONS OF TEACHING MACHINES

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ABSTRACT

A STUDY IN THE APPLICATIONS OF TEACHING MACHINES

Three experiments were conducted to compare the effects of programed learning with traditional teaching methods at a naval electronics school. Linear programs were constructed in DC and AC Electricity, and in Calculus for Electronics. Experiment IA compared the results of instruction by television and by programed learning using a machine and a programed text in DC Electricity. Experiment IB compared the results of instruction by conventional classroom lecture with the results using a teaching machine and a programed text in AC Electricity. Final examination grades showed no significant differences between methods of instruction in either experiment.

Experiment II compared effects attributed to the method of homework preparation in Calculus. Two groups were used. One group used a regular textbook and the other used a programed textbook. Examination scores were significantly higher for the group using a programed textbook.

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FOREWORD

Purpose

The purpose of this investigation was to supplement the information available on the effectiveness of programed instruction. The study deals specifically with certain technical subject matters as taught in a military setting. In addition, the effects of ability level were studied.

Two methods of programed instruction (teaching machine and programed booklet) were compared with television and conventional lecture presentations in learning basic electricity. Moreover, the effectiveness of programed instruction (programed booklet) in place of homework assignments in learning calculus was investigated.

Results

In DC and AC electricity, when the measure was a final unit examination, no significant differences among the three methods of instruction were found. Nor was the efficiency of the methods significantly affected by the ability of the groups as measured by GCT-ARI scores.

When the measure was final grade (40% of which was the unit examination score), a significant difference in the instructional methods was found in both DC and AC electricity with the TV -- conventional lecture group scoring highest. In DC electricity, measured ability did not significantly affect the relative merits of the instructional methods. In AC electricity, the method of instruction was affected by measured ability, probably because the machine group proved to be the poorest of the low groups and best of the high groups.

Two conventionally taught classes were added to the above three as additional controls and compared on final grades. For DC electricity no significant differences among classes were found. For AC electricity, a significant difference was found with a lecture group scoring highest.

The time to finish the DC electricity course was 31.5 hours for the TV, 36.4 hours for the machine group, and 25.4 hours for the programed booklet group. For AC electricity, course times were: lecture -- 31.5 hours, machine -- 25.4 hours, and programed booklet -- 19.6 hours.

No significant differences among instructional methods were found on the basis of the administration of a supplementary examination in AC/DC electricity.

An experimental group using a programed booklet in calculus for homework was compared on four examinations with a group using conventional homework techniques. The experimental group proved to be significantly superior.

The programed booklet method appeared less affected by ability levels than either of the other two methods and also took much less time to complete than either of the other methods. Both the programed booklet and machine groups completed AC electricity more rapidly than DC electricity.

Implications

The savings in time which resulted, particularly from the use of the programed booklets, could be used profitably in naval training either by adding material or shortening courses. Also of interest to naval training is the tendency for the different ability groups to emerge more like each other after using programed booklets. This leveling effect, found in other studies of programed instruction, tends to bring the low aptitude portion of a group closer to the group average for a given course. Thus it may be possible, in some instances, to use certain manpower groups that might otherwise be unsuitable.

The use of programed booklets as homework material represented a unique employment of automated instruction. The significant improvements that resulted suggest that this supplementary use should be explored in a number of settings.

The 10,600 frames of programed material constructed for this study are available for further study and use in military training.

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RECOMMENDATIONS

The results of the three experiments reported here indicate:

1. The use of programed learning methods is essentially as effective as conventional methods of instruction, such as classroom lecture either by closed circuit television or by live instruction, for teaching DC and AC electricity.

2. DC and AC electricity can be taught in considerably less time by programed textbooks than by conventional methods and in about the same time by a teaching machine as by conventional methods.

3. A homework assignment in a program format is more effective than contional homework assignments (reflected in examination score).

On the basis of these findings the following recommendations are made:

1. Programed instruction can profitably be used in the teaching of classroom subject matter. Not only can programed instruction be used in place of lectures but it also can profitably be used in lieu of traditional homework materials.

2. The use of a programed text is as efficient as the teaching machine used in these experiments. However, further investigation is recommended as to whether or not a teaching machine or a programed text is most efficient in teaching a particular ability group.

3. It is also recommended that, according to the present state of the art, the writing of programed materials must be considered a dynamic rather than a static process. One of the basic principles of programed learning involves a series of thorough revisions based on responses actually made by the students. In this way, ambiguous statements and instructions are revised and additional examples added to difficult portions.

4. Prepared outline notes or notes constructed by the student from cues in the program are more beneficial than haphazardly taken notes and provide a ready reference for the student after completion of programs. This should be considered when offering programed courses.

BRIEF OF THE STUDY

Introduction

Recent developments in psychology and education (Lumsdaine and Glaser, 1960) have demonstrated that students can proceed to mastery of a subject through programed instruction. For this to happen, however, the material from which the student learns must be carefully prepared or "programed" in a special way. The basic idea is that the most efficient, pleasant, and permanent learning occurs when the student proceeds through the course by a large number of small, easy-to-take steps. During the learning, the student will be responding actively and receiving immediate confirmation of the correctness of his responses. He can progress as rapidly or as slowly as he wishes.

In order to provide answers as to the appropriateness of implementing the the teaching of particular course material in naval classes through programed instruction, a study was conducted at a naval electronics school. It was decided that the following subjects as taught at the Service School Command, U. S. Naval Training Center, Great Lakes, Illinois, should be programed:

a) DC and AC Electricity. These are the basic courses taught to recruits at the Electricity and Electronics Preparatory School.

b) Refresher Mathematics. Since many recruits show a deficiency in the elementary mathematical operations such a program was considered appropriate.

c) Calculus for Electronics. This is part of the Computers Basic Course as taught in the Class "C" School.

The four programs developed (DC and AC Electricity, Calculus, and Refresher Mathematics) were prepared by subject-matter experts and programers supplied by the contractor. In preparing the programed courses, use was made of naval textbooks currently being used. Pre-validation work was done on all programs using subjects comparable in intelligence and age to those students for whom the courses were being prepared. In addition, for the DC Electricity program it was possible to pre-test on a large group of subjects comparable to naval recruits in an actual field (classroom) situation. Unfortunately, due to lack of time, this field pre-testing was not possible for AC Electricity, Calculus, and Refresher Mathematics programs. However, all programs were constructed so that the final revision would yield no more than five percent error rate.

During the period from July 31, 1961, to September 22, 1961, three experiments in programed learning were performed on naval personnel attending service schools at Great Lakes. The student groups involved consisted of enlisted personnel who had been selected by standard naval procedures without regard to the proposed experiments.

All three experiments dealt with the use of programed learning in two instructional situations. One experimental situation (Experiment IA and IB) compared the effectiveness of programed learning (use of a teaching machine or a programed textbook) with the effectiveness of closed-circuit television instruction and that of a "live" instructor.

The second situation (Experiment II) compared methods of homework preparation in an attempt to determine whether it is more effective to use regular homework assignments or homework prepared by using a programed text.

Experiment IA was carried out among classes being taught an introductory course in DC Electricity. In Experiment IB, the students involved were being taught an introductory course in AC Electricity. The students in Experiment II were being taught a course in the Basics of Computers of which Calculus is approximately one-half of the course. At the time, it was hoped that a refresher mathematics course could be included as an introduction to the electricity courses but lack of time due to the late arrival of the recruits prevented this. However, in the Calculus program the first nine units of instruction consisted of a review of algebra.

During the period that the experiments were being conducted the contractor assigned a research psychologist to the Great Lakes Training Center. In this capacity, he was responsible for distribution of the courses to the students, for explaining the use of teaching machines and programed textbooks, for collection and construction of evaluation data, and for coordination of the experiments with the school's instructional staff.

In the pages that follow, the experiments are presented in detail including the problem involved, the method of approach, materials used, special procedures involved, and a final discussion of results. Numerous tables and graphs are included in support of the text.

EXPERIMENT IA

PROBLEM

The purpose of this experiment was to investigate the variable of the method of instruction and its effect upon class performance as measured by the final examination grade in a course in DC Electricity.

This experiment was designed to investigate the difference between final examination grades of classes receiving instruction by television and classes receiving instruction by programed methods of learning. Two kinds of programed learning, each with identical content, were studied: (a) a teaching machine and (b) a programed textbook. Both methods were compared with the television presentation and with a previous lecture presentation.

Also investigated in this experiment were the differences in final performance between classes using the two forms of programed learning.

METHOD

THE EXPERIMENTAL SAMPLE

The Ss (subjects) were 120 enlisted men assigned to the Service School Command, United States Naval Training Center, Great Lakes, Illinois for the purpose of attending the Electricity and Electronics Preparatory School and eventually receiving the rating of Electronic Technician. These Ss were assigned by the Naval Bureau of Personnel and the experimenters had no control over their selection and assignment prior to the beginning of the experiment.

Due to the fact that the Ss did not all arrive at the school at the same time, and some did not arrive until the day classes started, it was not feasible to administer any form of pre-test without interrupting the schedule of instruction set by the school. Therefore no attempt was made to ascertain either the Ss' prior knowledge of the subject to be taught or to control for variations in the Ss' backgrounds other than matching by using a combination of GCT and ARI scores as explained later under PROCEDURE.

MATERIALS

The instructional material for the programed learning groups (experimental groups) consisted of a program in DC Electricity designed specifically for the U. S. Navy. Sample pages of the program appear in Appendix A. Each S, using one of the two forms of programed instruction described below, received a total of 10 sections with an average of 310 frames, or steps, per section.

The teaching machine used in this experiment was the Min/Max of TMI-Grolier, Albuquerque, New Mexico. Sample instructions for the manipulation of the program in the machine and a picture of the machine are shown in Appendix A-5.

The programed textbook consisted of the learning materials described above, with the exception that the materials were bound at the top of the pages with a plastic binder. The S moved a cardboard mask down these pages in order to read the material one frame at a time and to make his response for each frame.

Each S, using one of the two forms of programed learning, received a set of prepared notes each day covering the material in that daily increment of the program. These prepared notes (see sample in Appendix A-10 ff.) were designed to replace the notes which the S would normally take during a lecture and were to be used for a review on a daily basis and for preparation for the final unit examination. The notes became the property of the S whereas the program itself did not.

At the end of the course all Ss were given the same unit examination which was prepared by the Electricity and Electronics Preparatory School Examination Center.

PROCEDURE

As a basis for matching and controlling Ss' ability, standard U. S. Navy test scores were used. These tests were the General Classification Test (GCT) and the Arithmetic Ability Test (ARI) which were administered to the Ss at some time prior to their assignment to this experiment. The total score of these two tests was obtained for each S and the mean score of the 120 Ss was used as a basis for dividing the total group in half. These halves were designated High (H) and Low (L). These two groups were randomly divided into three sections each for a total of six sections and were designated as H-I, H-II, H-III and L-I, L-II, L-III. One section from each half was randomly assigned to one of three learning conditions, television, programed text or teaching machine. The means and SDs are shown in Table 1.

TABLE 1

Means and SDs of ARI and GCT Scores Combined

N = 20 for Each Group

	HIGH			LOW		
	H-I Min/Max	H-II Programed Text	H-III Television-Lecture	L-I Min/Max	L-II Programed Text	L-III Television-Lecture
Mean	129.00	129.05	129.05	114.75	114.80	114.55
SD	4.89	4.78	5.35	5.17	5.13	5.74

The S's daily work is normally divided into several parts.

Part I consists of a rapid homework review and a daily quiz (at the instructor's discretion).

Part II consists of the lecture covering more thoroughly the homework assignment with a broader explanation and discussion of the material using films, slides and other training devices.

Part III consists of laboratory experiments which put into practice the theory taught in the lectures.

In this experiment, the two groups designated to receive the conventional method of instruction were taught by an instructor on television during Parts I and II. In Part I, the television instructor asked the questions for a daily quiz and the regular classroom instructor monitored the class and scored the quizzes. In Part II, the television instructor lectured for 15 to 30 minutes depending upon the material presented, then the classroom instructor answered individual S's questions for 10 to 15 minutes. This procedure was repeated until the whole topic for the particular day was covered.

The groups designated to receive instruction using the programed material received their homework review and daily quizzes from their regular classroom instructors during Part I of the school day.

The instructors assigned to the four groups of programed learning gave these sections identical daily quizzes to prevent "easy" or "difficult" quizzes from differentially affecting the final grades of the classes.

Part II consisted of the Ss individually working through the unit of the program assigned for that day, using either the teaching machine or programed textbook.

Part III for these four groups was the same as that for the two regular groups. The same laboratory practice work was accomplished by all six groups. During this portion of the day each instructor returned to his regularly assigned class.

Each S, using programed material, worked at his own rate of speed until either the S completed the unit or the allotted time for completion of the unit during the class time expired. Those Ss who did not complete the unit of the program during the allotted time were permitted to return to the school after normal class time to complete the unit.[1]

If the S had a question about the content of the program while working, the classroom instructor instructed the S to reread the frame. If the question remained unclear to the S, the instructor read the frame aloud. If the question still remained unclear, the instructor reread the frame aloud to the S emphasizing particular words in the frame. If this procedure did not solve the problem, the instructor took the S to the back of the room away from the program and answered the question directly. Questions about the content of the program that required assistance from the instructor occurred on the average of twice per week per class.

At the termination of each unit in the programed learning sequence, the Ss received the notes prepared from the program (page 5). Sample notes appear in Appendix A-10 ff.

All Ss were given the standard unit examination in DC Electricity during the tenth day of instruction.

RESULTS AND DISCUSSION

The means and SDs of both the final examination scores and the final grades are presented in Table 2 and Table 3 respectively. Analyses of variance performed on these data (Table 14, Appendix A-1) indicated no significant difference in final examination scores attributable to the method of instruction, but did indicate a difference significant at the .01 level in the final grade due to the method of instruction (Table 15, Appendix A-3).

The scores reported in Table 2 present the mean of each section on the final examination based on 50 questions and a maximum or perfect score of 40 points.

[1] A study hall is regularly maintained by the school for use by students who the instructors feel need extra time to study.

TABLE 2

Means and SDs of Examination Scores (DC Electricity)

N = 20 for Each Group

	HIGH			LOW		
	Min/Max	Programed Text	Television-Lecture	Min/Max	Programed Text	Television-Lecture
Mean	37.00	36.21	37.40	32.65	35.30	34.20
SD	2.57	3.00	1.65	3.53	3.68	3.49

The analysis of variance performed on the examination scores indicate that there is no significant difference attributable to the method of instruction. Analysis of these particular data is appropriate to this experiment since no attempt was made in the program to teach laboratory or experimental procedures to the students. The examination scores reflect what the Ss gained from the program or from the television lecture alone. A graph of these scores is shown in Figure 1, Appendix A-2.

The scores reported in Table 3 present the mean final unit grade for each group based on 100 points maximum total. These 100 points consist of the following:

		TOTAL
Final Examination		40
Classroom Grade:		
homework	5	
daily quiz	10	
classroom attitude	5	20
Laboratory Grade:		
classroom laboratory experiments	20	
performance examination	20	40
		100

The instructor's evaluation of the student appears in the final unit grade and thus has an effect on the S's final grade. An example of the breakdown of grade points is given above. In the four programed learning groups the instructors could not get to know the Ss as well as those

instructors in the conventional classes since the instructors in the programed classes were rotated daily.

TABLE 3

Means and SDs of Final Unit Grade (DC Electricity)

N = 20 for Each Group

	HIGH			LOW		
	Min/Max	Programed Text	Television-Lecture	Min/Max	Programed Text	Television-Lecture
Mean	84.40	86.37	88.95	80.15	84.70	86.05
SD	7.38	7.56	6.63	7.74	6.15	6.01

A graph of these scores is shown in Figure 2, Appendix A-4.

Analysis of variance of these data is shown in Table 15, Appendix A-3.

All Ss knew of the experiment and this may have had an effect on the final unit grades. As a means of control for the "Hawthorne effect," described by Roethlisberger and Dickson (1939), grades and ability measurement scores of two previous classes were obtained and are presented in Table 4 and Table 5.

A class four months prior to the start of this experiment was used as one control group. This class was one of the first to receive instruction via television. A class one year prior to the start of the experiment was also used as a control group because the school personnel indicated that the caliber of the classes tended to duplicate themselves from year to year according to the time of assignment to the school.

TABLE 4

Means and SDs of Final Unit Grade (DC Electricity) and GCT and ARI Scores For a Class Four Months Prior to Experiment

N = 82

	FINAL GRADE	GCT and ARI COMBINED
Mean	83.40	123.45
SD	7.84	9.26

TABLE 5

Means and SDs of Final Unit Grade (DC Electricity) and GCT and ARI Scores For a Class One Year Prior to Experiment

N = 105

	FINAL GRADE	GCT and ARI COMBINED
Mean	85.44	Not Available
SD	9.44	Not Available

It will be noted that although the maximum difference among examination scores (Table 2) is 4.75, this difference is between what was considered a high intelligence group and a low intelligence group, and the analysis of variance for these scores indicates that this difference is not due to the method of instruction but to differences of measured ability.

An analysis of variance performed on the data shown in Tables 3, 4, and 5 showed that no significant differences occurred among these classes. The results of this analysis of variance are shown in Table 16, Appendix A-4

Table 6 shows the average time required for the Ss in the programed learning groups to complete the program.

TABLE 6

Average Time Required for Program and Unit Completion

	Min/Max		Programed Text	
	Program	Unit	Program	Unit
High	33.79 hours	202.75 min	21.96 hours	131.97 min
Low	38.96 hours	233.80 min	28.85 hours	173.10 min

The average time spent in a lecture by an S from a conventionally taught group is approximately 30-33 hours.

This indicates that when Ss are permitted to proceed through material at their own rate, they will vary considerably around the mean time spent in a conventionally taught class where all Ss proceed at the same pace. This further indicates that the average lecture is too rapid for some Ss and too slow for others. It should be noted that Ss who finished early read the following day's assignment.

Examining the data from Table 2 (page 8), the television presentation score is higher than either the Min/Max or the programed text with the high ability groups. But with the low ability groups the programed text is more effective than either the television presentation or the Min/Max.

It should also be noted that the programed text method resulted in both the high and low ability groups achieving mean examination scores close to each other, but the other two methods of presentation showed a greater difference between high and low ability scores for each method of presentation.

Table 3 (page 9) also shows that the programed text method of instruction resulted in less difference in final grades between ability groups than did the use of the other methods of instruction. However, if the mean grades for the ability groups are combined, the television presentation was the highest.

EXPERIMENT IB

PROBLEM

The purpose of this experiment was the same as that of Experiment IA and was in fact a continuation of Experiment IA. It is treated as a separate experiment due to changes in method of instruction for two class sections and changes in material presented for all sections. Both changes are noted below in the section titled METHOD.

METHOD

THE EXPERIMENTAL SAMPLE

The groups consisted of the same Ss used in Experiment IA (page 4).

Different instructors were assigned to the sections as is usual in this school. One group, however, retained the same instructor that was used in Experiment IA. This group is noted as the High-Lecture group in this experiment.

MATERIALS

The instructional material for the programed learning groups in this experiment was a course in AC Electricity designed specifically for the U. S. Navy. Sample pages from the program appear in Appendix B-6 ff. Each S received a total of 10 units with an average of 284.7 frames per unit. The groups designated High- and Low-Lecture received instruction from a "live" instructor in this experiment as opposed to a "television" instructor in the previous experiment. This procedure of teaching DC Electricity via television and teaching AC Electricity via "live" instructors is the normal procedure for the school. These groups are noted as Lecture groups in this experiment.

PROCEDURE

The procedure in this experiment was the same as that reported in Experiment IA (page 5).

However, at the conclusion of the program in AC Electricity each S in the programed learning groups was asked to write his opinions of the method of instruction. The S was to include his personal feelings about the method as to whether he liked it or not, its value to him personally, and his criticisms and comments.

An attitude questionnaire was not used for this because of the expense involved in building and validating such a questionnaire for this special case.

All Ss were given the standard unit examination in AC Electricity during the 20th day of instruction.

RESULTS AND DISCUSSION

The means and SDs of both the AC Electricity final examination scores and the final grades appear in Table 7 and Table 8 respectively.

The examination scores of Table 7 are based on a maximum of 40 points as described on page 7.

TABLE 7

Means and SDs of Examination Scores (AC Electricity)

N = 20 for Each Group

	HIGH			LOW		
		PROGRAMED			PROGRAMED	
	MIN/MAX	TEXT	LECTURE	MIN/MAX	TEXT	LECTURE
Mean	33.61	31.78	34.90	28.50	30.05	31.85
SD	5.40	6.02	3.10	4.20	5.90	5.20

An analysis of variance performed on these data (Table 19, Appendix B-1) indicated that there was no significant difference among groups in examination scores due to the method of instruction.

Again, since no attempt was made in the program to teach laboratory or experimental procedures, the examination scores reflect only what the Ss gained from the program or from the lecture. A graph of the means of the examination scores is shown in Figure 3, Appendix B-1

The scores reported in Table 8 are based on 100 points maximum total as described in page 8, and present the mean final unit grade for each group on the unit of AC Electricity.

TABLE 8

Means and SDs of Final Unit Grade (AC Electricity)

N = 20 for Each Group

	HIGH			LOW		
		PROGRAMED			PROGRAMED	
	MIN/MAX	TEXT	LECTURE	MIN/MAX	TEXT	LECTURE
Mean	89.84	84.63	88.30	73.80	82.68	85.05
SD	6.70	7.80	6.30	9.40	8.80	7.80

The analysis of variance performed on the data (Table 18, Appendix B-3) shows a significant difference in final grades at the .025 level of confidence but since the interaction between method of instruction and ability level was also significant, the relative merit of a given method will be related to the ability of the group using it.

Table 9 contains the means and SDs of two classes which completed the course prior to this experiment as noted on page 9.

TABLE 9

Means and SDs of Final Unit Grade (AC Electricity)

Classes Prior to Experiment

	N = 76	N = 97
	4 Months Prior to Experiment	One Year Prior to Experiment
Mean	86.6	81.85
SD	8.47	9.29

A graph of the means of the final unit grades for the classes in Table 8 is shown in Figure 4, Appendix B-3.

An analysis of variance performed on the data shown in Tables 8 and 9 showed that significant differences occurred among these classes. The results of the analysis of variance are shown in Table 19, Appendix B-4, in which each of the three methods of Table 8 were combined.

Table 10 shows the average time required for the Ss in the programed learning groups to complete the program.

TABLE 10

Average Time Required for Program and Unit Completion

	MIN/MAX		PROGRAMED TEXT	
	PROGRAM	UNIT	PROGRAM	UNIT
High	24.12 hours	144.71 min	17.76 hours	106.53 min
Low	26.81 hours	160.85 min	21.47 hours	128.79 min

The average time spent in a lecture by an S from a conventionally taught class is approximately 30 - 33 hours as was noted in Experiment IA.

As a means for investigating the instructor bias in this experiment, a special examination was given to all classes involved in the experiment. This examination (see Appendix B-9 ff.) was prepared by personnel at the United States Naval Training Device Center, Port Washington, New York and covered the material which was taught in both the DC and EC Electricity units. The purpose of this examination was to determine if instructors tended to emphasize material included in the regular examinations.

The policy of the school is to give a review examination to the students in order to acquaint them with the type of questions involved in the regular unit examination. The special examination replaced the review examination for these classes.

These special examination scores (class means and SDs) are reported in Table 11.

TABLE 11

Means and SDs of Special Examination (DC and AC Electricity)

N = 20 for Each Group

	HIGH			LOW		
		PROGRAMED			PROGRAMED	
	MIN/MAX	TEXT	LECTURE	MIN/MAX	TEXT	LECTURE
Mean	23.89	23.05	24.45	22.00	22.05	20.45
SD	2.84	3.17	3.20	3.91	3.39	3.61

The analysis of variance performed on this data (Table 20, Appendix B-4) shows no significant difference in scores due to the method of instruction.

The significant difference in final unit grades reported on page 14 can be attributed in a large part to the extremely low score of the low ability group using the Min/Max method of instruction. It should be noted here that this same significant difference did not appear in the examination grades.

EXPERIMENT II

PROBLEM

The purpose of Experiment II was to determine whether any difference in examination scores would exist between classes in calculus using conventional homework assignments and those using a prepared programed text as homework. Ss were instructed in calculus for four hours per day and in computer theory for the remaining four hours. Because the final grade was a combination of the two, this final grade could not be used for comparison.

METHOD

THE EXPERIMENTAL SAMPLE

The Ss in the experimental group were 13 enlisted men and one officer in the U. S. Navy assigned to Electronic Technician "C" School, U. S. Naval Training Center, Great Lakes, Illinois

Ages and abilities of the Ss were used as comparisons between the experimental and control groups. The ability measure used was the combination GCT and ARI scores as explained in Experiment IA. These data appear in Table 12.

TABLE 12

Means and SDs of GCT and ARI (combined) and Age

	N = 16		N = 18	
	EXPERIMENTAL GROUP		CONTROL GROUP	
	GCT & ARI	AGE	GCT & ARI	AGE
Mean	131.14	22.82 yrs.	124.61	30.59 yrs.
SD	8.97	4.16 yrs.	10.29	3.97 yrs.

During the course of this experiment, one S of the experimental group was dropped because he was transferred from the school by direction of the Navy. Two officers from the Chilean Navy were assigned to the class two weeks subsequent to its beginning. These two Ss were given a "cram course" by the instructor personnel to allow them to catch up to the rest of the class.

The control group was a class enrolled for the identical course four weeks after the start of this experiment and the Ss used a traditional calculus textbook for homework assignments.

MATERIALS

The "Self-Tutor" programed textbook manufactured by TMI-Grolier of Albuquerque, New Mexico was used in this experiment. A picture of this appears in Appendix C-3 along with the standard instructions for its use.

The program was designed specifically for the U. S. Navy and created as an adjunct to the particular calculus course presently being taught. A sample page of this program appears in Appendix C-4.

As a further aid to the Ss, a programed notebook was prepared by each S as he went through the program. A sample page of the programed notebook appears in Appendix C-5. This is explained more fully under the section titled PROCEDURE.

PROCEDURE

At the first meeting of the class which was designated as the experimental group, the experimenter met the class and explained the use of the program. The program was presented as a new method of doing homework in order to minimize the Hawthorne effect with this class. They were not informed that they were subjects for an experiment or that they would be compared with another class. The class was informed that the completed pages of the program would be scored as a check on the program and, even though they could look ahead for the correct response, they would derive more benefit from the program if they refrained from observing the confirmation until they had made their response.

Also, they were told that if they had questions while completing the program to ask the instructor at the next class meeting if the question was not answered subsequently in that section of the program.

The Ss received lectures in calculus during one-half of the school day and lectures in computer theory and maintenance during the remaining half of the school day. They were given conventional homework assignments in computer theory and given sections of the program to complete as homework in calculus.

The programed notebook consists of numbered pages and numbered references on the pages. As the S completed a particular frame within the program, he was signaled that the confirmation was to be copied within the appropriate area in the programed notebook. At the termination of the program, the S had completed the program and as a future reference he had made a notebook of the most important ideas and theorems in the course.

RESULTS AND DISCUSSION

During the eight weeks duration of the course, the Ss were given a total of eight examinations. Four of these examinations covered material other than calculus. The remaining four examinations covered calculus and the mean scores for both groups are reported in Table 13.

TABLE 13

Mean Examination Scores of Experimental and Control Groups

	EXPERIMENTAL	CONTROL
Examination No. 1	84.57	73.78
Examination No. 2	82.07	61.94
Examination No. 3	78.73	64.44
Examination No. 4	82.40	76.44
Mean of Examination Scores	81.94	69.15

An analysis of variance performed on the means of the examination scores showed a significant difference at the .025 level of confidence (Table 23, Appendix C-1).

Analyses of variance performed on age and ability (Tables 21 and 22, Appendix C-1) showed significant differences in age but not ability for these two groups.

For further study, an analysis of covariance was performed on the data of age and examination scores. This showed a significant difference in examination scores with the age factor held constant. This is reported in Table 24, Appendix C-2.

The analyses performed indicate that the use of a programed textbook as a homework assignment will increase the overall examination scores compared to the examination scores obtained by Ss performing conventional homework assignments.

The main comment from the Ss was that the programed textbook helped them to understand more thoroughly the problems by going through the processes involved in a step-by-step manner.

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Headquarters, AF Systems Command Electronic Systems Division, L. G. Hanscom Field, Bedford, Massachusetts, MKD: Dr. Sylvia Mayer.

Commanding Officer, U.S.C.G. Training Station, Groton, Connecticut

Sheffield University, Department of Psychology, Sheffield 10, England, MKD Dr. John Annett

U.S. Naval Personnel Research Field Activity, San Diego 52, California, MKD: Dr. Eugenia N. Kemp

Aeronautical Systems Division (ASBST-0), Wright-Patterson AFB, Ohio MKD: Dr. A. Ugelow

Commanding Officer, Nuclear Weapons Training Center, Atlantic, Norfolk 11, Virginia, MKD: CAPT J. H. King

University of Arizona, Department of Psychology, Tucson, Arizona, MKD: Dr. Sidney L. Pressey

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The MITRE Corporation, P.O. Box 208, Bedford, Massachusetts, MKD: Mr. Chas. S. Morrill

Sandia Corporation, Technical and Trades Training Division 3132, Sandia Base, Albuquerque, N.M., MKD: Mr. Robert F. Utter

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ADM Alfred M. Pride, USN (Ret.), CNO Board, Washington 25, D.C., MKD: Mr. Jamison

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APPENDIX A

TABLE 14

Analysis of Variance of Examination Scores (DC Electricity)

Source	df	ss	ms	F-ratio
Columns (Method of Instruction)	2	5.51	2.75	.30
Rows (Measured Ability)	1	185.53	185.53	18.89***
Rows X Columns	2	37.38	18.69	1.90
Within	113	1119.88	9.82	
Total	118[1]	1348.30		

***Significant at the .001 level

This analysis of the data obtained indicates that the significant differences among scores is attributable to the division of the total class into a high and a low group and not attributable to the method of instruction.

It should be noted here that the instructor of the class designated as "Low-Machine" (L-II) was antagonistic toward programed learning. This may have influenced this instructor's grading of the Ss in his regularly assigned class. It has previously been mentioned how large a part of the Ss final grade is determined by the instructor. (Page 8)

Figure 1 (page A-2) shows that all of the high ability groups attained higher mean examination scores than did the low ability groups. This is a significant difference as shown in Table 14, and is due to a significant difference in ability between the high and low groups.

[1] This figure should be 119 since total df = (n - 1). One S left class H-II at the second meeting. Lindquist (1956) notes that one df must be subtracted from total and the mean value of the group entered as the missing value.

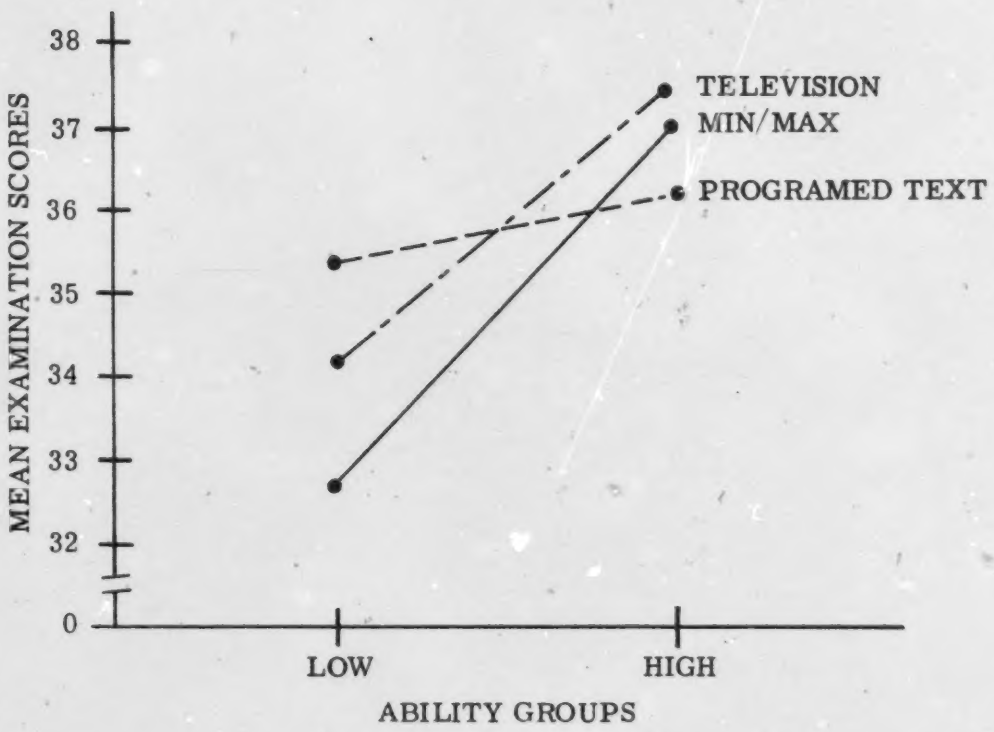

FIGURE 1. D C EXAMINATION GRADES

Visual inspection of Figure 1 shows the leveling effect of the programed text on the high and low ability groups. Although all high and low ability groups started out significantly different from one another, only the two groups that studied with a programed text became more alike. The groups that learned by a machine or from television still retained their significant difference in ability.

Table 15 shows the analysis of variance performed on the groups' final unit grades in DC Electricity. It should be noted that instead of being similar to Table 14 in significance of differences, the significant difference in final scores due to measured ability changed from the .001 level to the .05 level and the significant difference in final scores due to method of instruction changed from no significance to significance at the .01 level.

TABLE 15

Analysis of Variance of Final Unit Grade (DC Electricity)

Source	df	ss	ms	F-ratio
Columns (Method of Instruction)	2	556.28	278.14	5.29 **
Rows (Measured Ability)	1	256.14	256.14	4.87 *
Rows X Columns	2	34.34	17.17	0.33
Within	113	5937.91	52.55	
Total	118[1]	6784.67		

*Significant at the .05 level

**Significant at the .01 level

[1] This figure should be 119 since total df = (n - 1). One S left class H-II at the second meeting. Lindquist (1956) notes that one df must be subtracted from total and the mean value of the group entered as the missing value.

Figure 2 shows the final unit scores graphically. It will be noted from the graph that both the high and low groups using the Min/Max scored lower than the other groups.

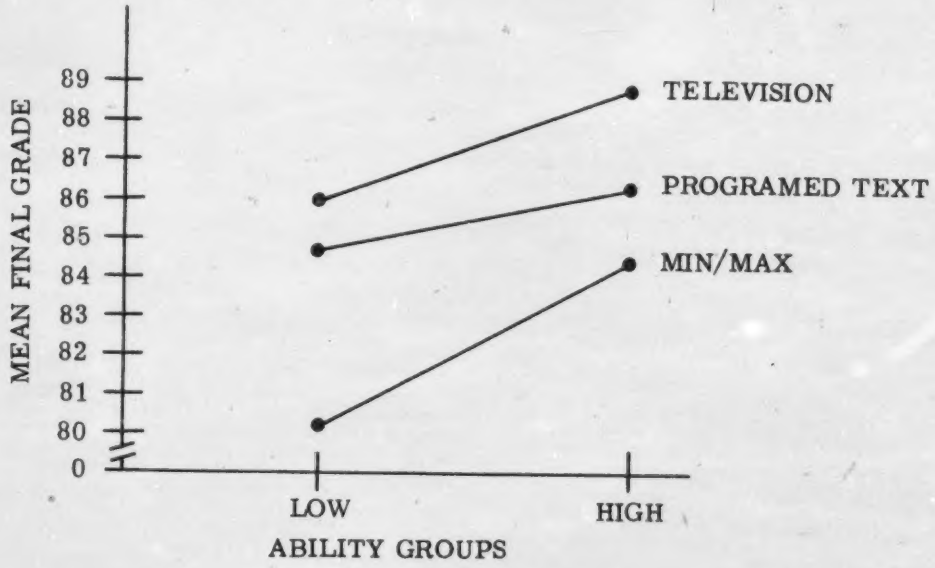

FIGURE 2. D C FINAL GRADES

TABLE 16

Analysis of Variance of Final Unit Grade for Five Classes (DC Electricity)

Source	df	ss	ms	F-ratio
Columns (Between Classes)	4	80.13	20.03	.003
Within	302	21324.40	70.60	
Total	306	21404.53		

This analysis was performed in the following manner. The High and Low ability groups were combined into cells according to their method of instruction which resulted in three groups. The four-month group and the one-year group made up the remaining two cells. This resulted in a 1×5 analysis of variance. The final results as shown in Table 16 indicate that there was no significant difference in final grades among these five groups.

The following pages describe the Min/Max Teaching Machine and how it is used.

SAMPLE INSTRUCTIONS

You are about to begin a new adventure in learning. These instructions tell you how to use your teaching machine and how to help others use it.

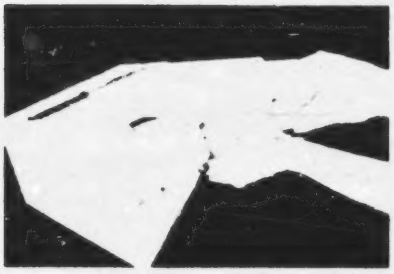

Figure 1. OPENING MACHINE

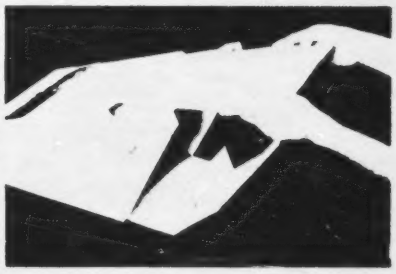

Figure 2. INSERTING PROGRAM

1. Tilt the TMI-Grolier MIN/MAX machine so that it rests on its back.
2. Open machine by pulling lip of tray toward you and pushing up on tray from underneath. (See figure 1.)
3. Pick up the sheets beneath this page and insert them in slot above tray. (See figure 2.)
4. Close machine by lifting up tray and pulling toward you until it snaps over the catch.
5. Tilt machine forward until it rests in reading position.

Figure 3. STARTING A SHEET IN THE MACHINE

Figure 4. STARTING A SHEET IN THE MACHINE

6. Place your thumbs and index fingers at the bottom of the starting slots on either side of the machine. (See figure 3.)
7. Separate the top sheet as you would do in separating a page of a book. Make sure you separate only the top sheet.
8. Push this sheet up until the top of the sheet is even with the top of the window in the machine. (See figure 4.)
9. From now on, follow the directions in the window of your MIN/MAX.

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Albuquerque, New Mexico

SAMPLE INSTRUCTIONS (CONT.)

2

This space is where the question will appear.

This space that is covered is where you will check your answer.

Now, place your pencil eraser in the advance slot and push paper up until you can see the space that was covered.

Use your pencil eraser to push paper up until this space is out of sight.

This space is where you will write your answer.

Every question space will have a blank like this _____.
Write the word which fills the blank.

HERE

Then use your pencil eraser and move the paper up to check your answer.

HERE

Push paper up to next question space.

Under this viewing glass is a one-way spring. If you move the paper down instead of up, this spring tears a hole in the paper. Try moving the paper down. Does the paper tear?

Write yes or no

HERE

yes

After you finish each sheet, push it all the way up until it falls down inside the machine. You are now at the end of this sheet. After you check your answer, push sheet up so it falls down inside the _____.

machine

Your MIN/MAX is designed so that you can change windows easily for different courses. The first page of the course tells which window to use with that particular _____.

course

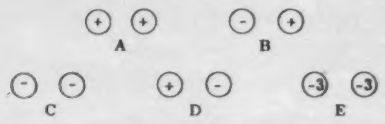
SAMPLE DC ELECTRICITY PROGRAM

16

A law of electricity is that "like charges repel each other."

Which of these pairs will repel each other?

Which of these pairs will attract each other?



Attract - B and D

Repel - A, C, and E

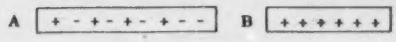
Attract -

Repel -

17

Two neutral objects were just rubbed together.

Electrons were transfered from object ( ) to object ( ).

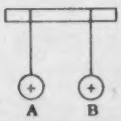


(B)

(A)

18

In the picture, ball A and ball B will be _____ _____ one another.



repelled from

19

Since all objects are composed of atoms which try to remain neutral, all objects also try _____

to remain neutral.

20

An object with a lack of electrons tries to neutralize its positive charge by seeking _____.

electrons

2-4

SAMPLE DC ELECTRICITY PROGRAM (CONT.)

21

Like charges _____.

Unlike charges _____.

repel

attract

22

You recall from arithmetic that to find the average of two numbers, A and B, you add A to B and divide by 2. $\frac{A + B}{2}$

If A = 6 and B = 4, what is their average? ( )

$\frac{6 + 4}{2} = \frac{10}{2} = +5$

23

The average of two numbers, A and B, if A = +4 and B = -6, is found as follows:

$\frac{(+4) + (-6)}{2} = \frac{-2}{2} = -1.$

Find the average of + 8 and - 4. ( )

$\frac{(+8) + (-4)}{2} = \frac{+4}{2} = +2$

24

What does one of the laws of electricity say about "like charges"? _____

Like charges repel each other.

25

Ball A is more positive than ball B.

Ball C is less positive than ball D.

Ball E is _____ positive than ball F.

Ball G is _____ positive than ball H.

A	(-2)	(-4)	B
C	(+2)	(+4)	D
E	(+7)	(+2)	F
G	(-8)	(-1)	H

more

less

2-5

SAMPLE DC ELECTRICITY PROGRAM (CONT.)

26

If the numbers are different, or the signs different, or both, the charges on two balls are said to be unequal.
Which of these pairs are unequal?

A (+2) (+2) B (+2) (-2) C (+3) (+6) D (-2) (-4)

B, C, and D

27

When two unequally charged objects touch, electrons flow from one to the other to equalize the charge.
In which of these pairs would electrons flow?

A (-4) (+4)
B (-5) (+3)
C (+2) (+2)
D (-6) (-6)

A and B

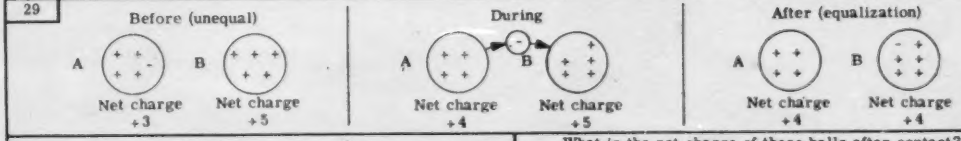
28

If two unequally charged + balls come together, some electrons will come off the less + one and flow onto the more + one.
Some electrons will flow from ( ) to ( ).

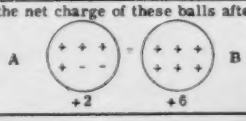
A (+6) B (+4)

B to A

29



What is the net charge of these balls after contact?



( )

(+4)

30

We know that + charges do not flow, but it seems that they do when a +5 and a +3 give an effective charge of +4.
What does actually flow? _____

an electron or a -charge

2-6

SAMPLE OUTLINE

WHAT ELECTRICITY IS

A. Matter

1. All matter is made of molecules

   a. Molecules are the smallest recognizable parts of matter

2. Molecules are made of atoms

   a. Atoms have two parts:

      (1) A nucleus ((N))
      (2) One or more electrons ((E))

3. The nucleus is in the center of the atom

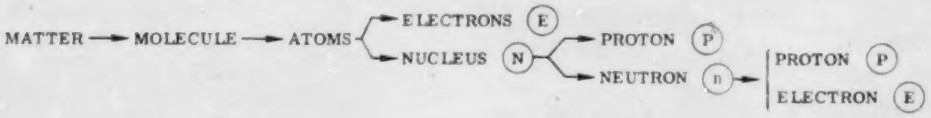
   a. The nucleus contains two parts:

      (1) neutrons (n)
      (2) protons (P)

4. The neutron consists of two particles bonded together:

   a. Proton and Electron

B. Diagram of Matter



C. Charges

1. Proton - Positive (+) charge
2. Electron - Negative (-) charge
3. Neutron - Neutral (0) charge

   a. Proton (+) and Electron (-) bonded together = 0 charge

D. Location

1. Electrons are found in two places

   a. In nucleus bonded with proton to form a neutron
   b. Travelling around the nucleus in orbits

2. Protons are found in the nucleus in two places

   a. Bonded with an electron to form a neutron
   b. Alone in the nucleus

E. Net Charge

1. The algebraic sum of the charges is called the net charge

   a. A +4 and a - 6 produces a net charge of - 2
      A - 3 and a - 7 produces a net charge of - 10

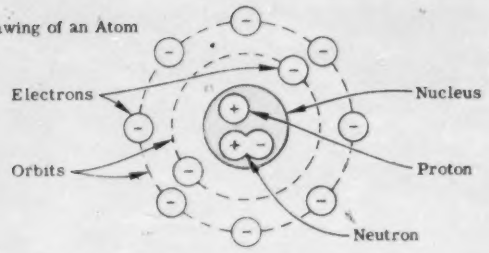
F. Neutral Charge

1. A neutral charge is a net charge of ZERO

   a. +3 and - 3 equals zero
      - 4 and - 4 does not equal zero

SAMPLE OUTLINE (CONT.)

G. Drawing of an Atom



H. Like and Unlike Charges

1. Like charges attract each other
2. Unlike charges repel each other
3. Electrons are held in orbit by the attraction of the nucleus

I. Free and Bound Electrons

1. Free electrons - In outer orbits
2. Bound electrons - In inner orbits

J. Electricity

1. Movement of free electrons from atom to atom

K. Force

1. A force is required to move an electron from its orbit
2. Forcing an electron from its orbit produces electricity

L. All atoms try to remain neutral

1. A neutral atom which loses electrons becomes positive
2. A negative atom which gains electrons becomes less negative
3. Atoms do not gain or lose protons
4. Atoms which gain electrons have a negative charge
5. Atoms with an excess of electrons have a negative charge

M. Static Electricity

1. Static electricity is a charge that is not moving

SAMPLE DC ELECTRICITY EXAMINATION

INSTRUCTIONS: Mark your answers on this sheet. Circle the correct answer.

1. The smallest physical particle into which an element can be divided is a/an

   (A) atom.
   (B) electron.
   (C) molecule.
   (D) proton.

2. What is the most common method by which static electricity is produced?

   (A) friction
   (B) heat
   (C) chemical
   (D) voltmeter

3. The device used to measure electromotive force is a/an

   (A) ohmmeter.
   (B) ammeter.
   (C) compass.
   (D) voltmeter.

4. An application of converting heat into electricity directly is the

   (A) primary cell.
   (B) photo electric cell.
   (C) thermocouple.
   (D) ammeter.

5. One of the uses of photo cells is

   (A) voltmeters.
   (B) ammeters.
   (C) light meters.
   (D) galvanometers.

6. The negative plate of a dry cell is made of

   (A) zinc.
   (B) lead.
   (C) copper.
   (D) carbon.

SAMPLE DC ELECTRICITY EXAMINATION (CONT.)

7. During discharge of a secondary cell, what happens to the material on the plates?

(A) It changes to hydrogen gas.
(B) It changes to lead sulphate.
(C) It forms a coating of lead peroxide.
(D) It forms a coating of ammonium chloride.

8. The active materials on the plates of the secondary cell are

(A) copper and zinc.
(B) sponge lead and lead peroxide.
(C) sponge lead and lead sulphate.
(D) zinc and carbon.

9. Which of the following statements is incorrect concerning magnetic lines of force?

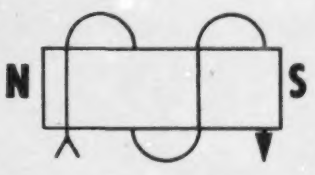
(A) They leave the north pole and enter the south pole.
(B) They do not pass through all materials.
(C) They do not cross or unite.
(D) They leave or enter the magnet at the poles.

10. Delicate instruments can be protected against the effects of magnetism by the use of a

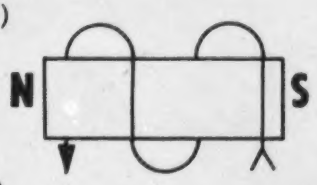
(A) magnetic screen of low reluctance.
(B) magnetic screen of high reluctance.
(C) magnetic insulator of low reluctance.
(D) magnetic insulator of high reluctance.

11. The drawing that shows the proper direction of electron flow with respect to magnetic flux is

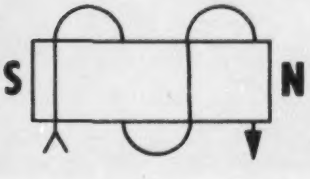
(A)



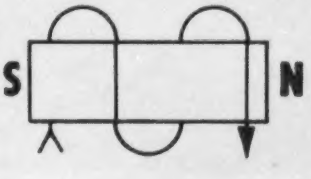
(B)



(C)



(D)



APPENDIX B

TABLE 17

Analysis of Variance of Examination Scores (AC Electricity)

Source	df	ss	ms	F-ratio
Columns (Method of Instruction)	2	151.69	75.85	2.87
Rows (Measured Ability)	1	327.88	327.88	12.41***
Rows X Columns	2	58.63	29.32	1.11
Within	112	2959.87	26.43	
Total	117 [1]	3498.07		

***Significant at the .001 level.

This analysis shows no significant difference in examination scores due to method of instruction.

Figure 3 shows that all of the high ability groups attained higher mean examination scores than did the low ability groups with the exception of the Low-Lecture group which scored slightly higher than the High-Programed Text group.

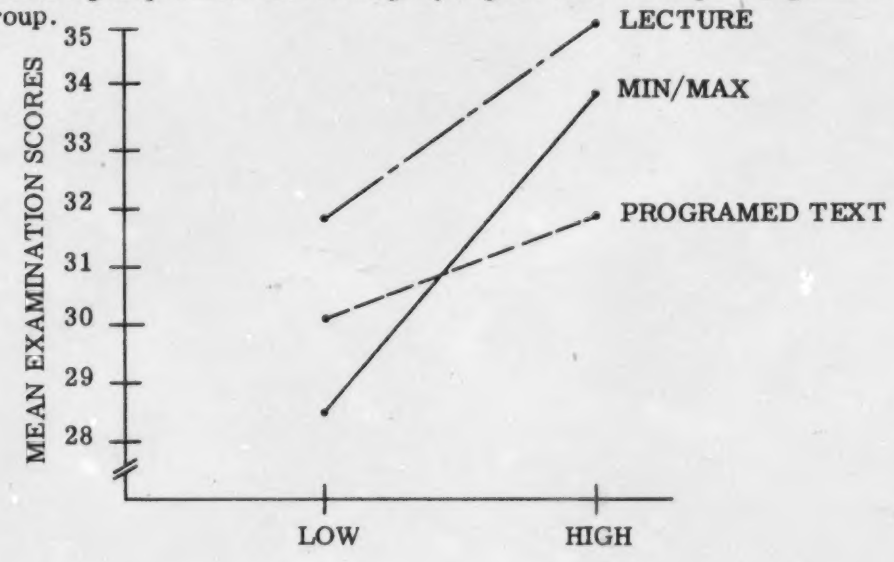


FIGURE 3. AC EXAMINATION GRADES

[1] Corrected for 2 missing cases. See Lindquist (1956)

Again, from Figure 3 it can be seen that the high and low ability groups which used the programed text tended to become more similar than did the groups being taught by the machine or by lecture.

Table 18 shows the analysis of variance performed on the groups' final unit grades in AC Electricity.

TABLE 18

Analysis of Variance of Final Unit Grades (AC Electricity)

Source	df	ss	ms	F-ratio
Columns (Method of Instruction)	2	474.31	237.16	4.73 *
Rows (Measured Ability)	1	1575.35	1575.35	31.44***
Rows X Columns	2	1163.63	581.82	11.61***
Within	112	5611.78	50.11	
Total	117[1]	8825.07		

*Significant at the .025 level

***Significant at the .001 level

Figure 4 illustrates graphically the positions of the group means of the final AC Electricity grade. It will be noted that the Low Min/Max group is below the other groups.

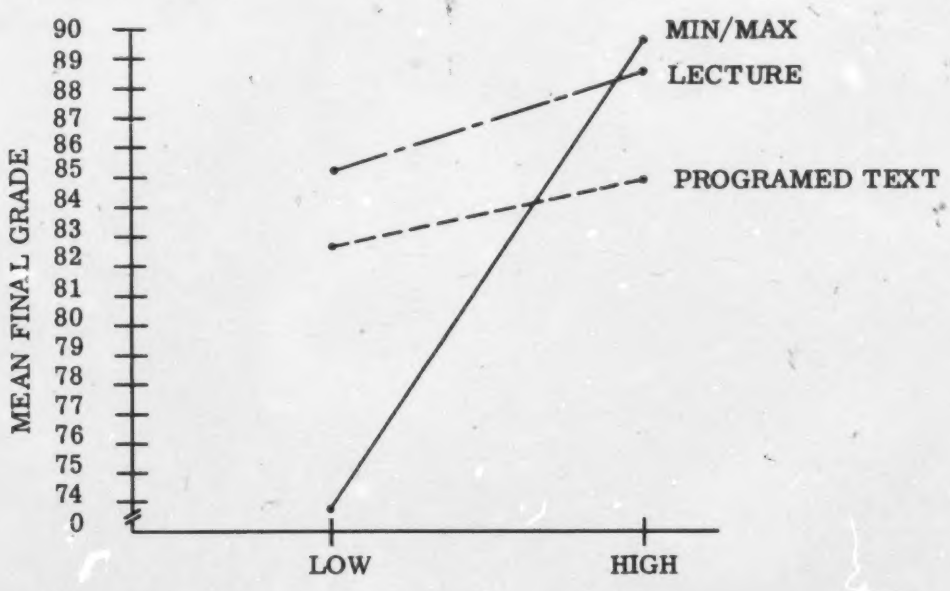


FIGURE 4. AC FINAL GRADES

[1] Corrected for 2 missing cases. See Lindquist (1956)

It will be noted that the method of instruction was significantly different but it also should be noted that the interaction was also significant. In short, one method of instruction was more effective with one ability group than it was with the other ability group. From visual inspection of Figure 4 it is apparent that the wide difference in learning with the Min/Max machine was the main contributing factor to the interaction.

TABLE 19

Analysis of Variance of Final Unit Grade for Five Classes (AC Electricity)

Source	df	ss	ms	F-ratio
Columns (Between Classes)	4	1437.94	359.48	4.67***
Within	288	22166.91	76.97	
Total	292	23604.85		

*** Significant beyond the .001 level

This analysis was performed in the manner described regarding Table 16 (page A-4), and shows significant difference in final grades among these five groups.

TABLE 20

Analysis of Variance of Special Examination Scores (DC and AC Electricity)

Source	df	ss	ms	F-ratio
Columns (Method of Instruction)	2	5.51	2.76	.23
Rows (Measured Ability)	1	158.44	158.44	13.29***
Rows X Columns	2	47.45	23.78	1.99
Within	112	1335.58	11.92	
Total	117[1]	1546.98		

***Significant at .001 level

The analysis of the special examination scores is given in Table 20.

[1] Corrected for 2 missing cases. See Lindquist (1956)

Examination of the various analyses of variance indicates that a significant portion of the final grade is determined by some factor or factors other than that which is measured by the written examinations.

The use of programed learning in this particular situation shows promise as an effective aid to obtaining the quality of instruction desired. Reorganizing the program that was used here to conform more closely with the changes in curriculum would be most beneficial. The evaluation of the instruction in this school is an on-going process and revisions in the method of instruction continually occur. And as these new techniques become perfected, the emphasis on certain areas of instruction shift. This type of revision should be considered also in evaluating the use of programed learning.

Revision of the program to coincide more closely with what is presently being taught would be quite beneficial to the students and to the school.

SAMPLE PROGRAM PAGES

11

Direct current is current flow which does not change direction.
In the conductor shown current always flows to the right.
What kind of current is flowing in the conductor?

_____ _____ I

direct current

12

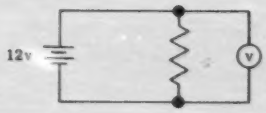
The abbreviation DC means direct current.

Since a battery is a source of direct current, we often call a battery a ( ) source.

(DC)

13

The battery supplies _____ current to the circuit shown.



direct

14

If electrons are flowing continuously past a point at a rate of one coulomb per second, one ampere of (AC/DC/NC) is flowing.

(DC)

15

Alternating current is current flow which changes in magnitude and direction at regular intervals.
In the conductors shown, current flows to the right and then to the left at regular intervals.
What kind of current is flowing in the conductor?

_____ _____

alternating current

11-3

SAMPLE PROGRAM PAGES (CONT.)

16

Alternating current is produced by an alternating current generator.

A battery (does/does not) produce alternating current.

does not

17

Direct current is abbreviated DC.

How would you expect alternating current to be abbreviated? ( )

(AC)

18

A generator that produces current which changes in magnitude and direction at regular intervals is called an

(NC/OK/DC/AC) generator.

(AC)

19

AC voltage can be increased or decreased by a transformer.

Which of the questions below can be answered from the statement given? ( )

1. Can resistance be increased or decreased by a transformer?
2. What can be used to increase or decrease an AC voltage?
3. How does a transformer increase an AC voltage?
4. Can a transformer change AC voltage to DC voltage?

(2)

20

"Step up" means to increase.

A step-up transformer is used to _____ AC voltage.

increase

11-4

SAMPLE OUTLINE

What AC Is

A. An advantage of AC current is that the voltage can be easily changed.

   1. AC is stepped up to high voltage for transmission, to avoid power loss.

   2. AC is stepped down for use in various devices.

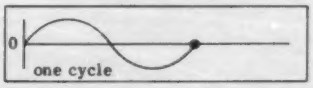
B. Rotating a coil in a magnetic field produces AC current.

C. AC current constantly varies in direction and magnitude.

   1. The rise and fall of AC current follows a waveform called a sine wave.

   2. A waveform represents the instantaneous values of the current or voltage in a circuit.

   3. A complete set of positive and negative values is called a cycle.



   4. The number of cycles per second (cps) is called the frequency.

   5. The standard commercial frequency is 60 cps.

D. AC voltage and current values are usually expressed in "effective" values.

   1. The effective value of an AC current is the amount of DC current that would be required to produce the same amount of heat in a resistor.

   2. The effective value of AC current is equal to 0.707 times the maximum value.

   3. Another name for effective (emf) value is "root-mean-square" (rms) value.

SAMPLE SPECIAL EXAMINATION IN DC-AC ELECTRICITY

Name:_____ Date:_____

PLACE IN THE PARENTHESES THE NUMBER OF THE MOST NEARLY CORRECT STATEMENT.

1. ( ) What is one property of a good electrical insulator?: (1) A high temperature coefficient; (2) Low opposition to electron flow; (3) High opposition to electron flow; (4) A low breakdown point.

2. ( ) The amount of heat generated by a resistor is determined by: (1) its wattage rating; (2) the formula $P = ER^2$; (3) its resistance and current through it; (4) its specific resistance and wattage rating.

3. ( ) The coulomb is a measure of: (1) work; (2) power; (3) charge; (4) voltage.

4. ( ) What determines the electrical properties of an atom? (1) The matter it is in compound with; (2) The charge possessed by its electrons; (3) Number and relative location of its electrons; (4) Speed and weight of electrons in its shells.

5. ( ) What determines the wattage rating of a resistor?: (1) The current through it; (2) The voltage drop across it; (3) Heat it will absorb without changing value; (4) Heat it will dissipate without destroying itself.

6. ( ) What is the result when the voltage applied to a circuit is doubled? (1) Current doubles; (2) Current drops by one-half; (3) Resistance doubles; (4) Resistance drops by one-half.

7. ( ) The voltage drop across a fixed resistor is doubled. The power dissipated by the resistor will be multiplied by: (1) 2; (2) 3; (3) 4; (4) 1/2.

8. ( ) What is the most desired characteristic of the core material of an electromagnet?: (1) High reluctance; (2) Low retentivity; (3) Low permeability; (4) High residuality.

9. ( ) In an a-c circuit made up of a coil and a resistor in series, increasing the number of turns of the coil will cause: (1) impedance to increase; (2) impedance to decrease; (3) no change in reactance; (4) reactance to decrease.

SAMPLE SPECIAL EXAMINATION IN DC-AC ELECTRICITY (CONT.)

10. ( ) What will increase line current in a series resonant circuit: (1) Decrease the 'Q' of the circuit; (2) Increase the circuit resistance; (3) Increase the capacitive reactance; (4) Decrease the circuit resistance.

11. ( ) Voltage is used as a reference point in parallel circuits because the: (1) current is equal through all branches; (2) voltage drops across all components are always equal; (3) voltage in any circuit is always constant; (4) voltage drops across all branches are equal.

12. ( ) In the a-c generator, the value of induced emf is NOT dependent upon: (1) number of conductors in series cutting the magnetic field; (2) number of times per second the field is cut; (3) strength of the magnetic field; (4) direction of rotation.

13. ( ) If average a-c voltage in a circuit is 63.7 volts, what is the rms voltage value?: (1) 45.0 volts; (2) 70.7 volts; (3) 90.7 volts; (4) 100.0 volts.

14. ( ) Inserting a core with greater permeability into an inductor will cause: (1) strength to decrease; (2) inductance to increase; (3) reluctance to increase; (4) reactance to decrease.

15. ( ) What is the phase relationship between current and voltage in a purely inductive circuit?: (1) Current lags voltage by 90°; (2) Current leads voltage by 90°; (3) Current and voltage are in phase; (4) Same as in a purely capacitive circuit.

16. ( ) The farad is the unit of measurement of the: (1) physical size of a capacitor; (2) property to oppose a change in voltage; (3) opposition to current flow; (4) relationship between resistance and capacitive reactance.

17. ( ) Additing capacitors in parallel is the equivalent of: (1) decreasing the dielectric constant of a single capacitor; (2) increasing the thickness of dielectric in a single capacitor; (3) increasing the plate area of a single capacitor; (4) decreasing the plate area of a single capacitor.

18. ( ) What is the purpose of a full-wave rectifier in an a-c meter: (1) It permits current to flow in both directions through the meter movement; (2) It causes a-c to flow thru the movement in the same direction during both alternations; (3) It blocks the current flow during one half cycle; (4) It allows the meter to indicate peak values.

SAMPLE AC ELECTRICITY EXAMINATION

1. The voltage in an AC power transmission line is limited by the:

   (A) diameter of the wire.
   (B) insulation.
   (C) impedance.
   (D) frequency.

2. An oscilloscope shows a 141.4 volt peak to peak sine curve reading when connected across the source in an AC circuit. The effective voltage across the circuit is:

   (A) 100 volts.
   (B) 50 volts.
   (C) 70 volts.
   (D) 141 volts.

3. Most AC meters are calibrated in:

   (A) average values.
   (B) maximum values.
   (C) effective values.
   (D) instantaneous values.

4. How much of the circuit current will flow through the moving coil of a thermocouple type meter?

   (A) None of the current.
   (B) Less than half of the current.
   (C) Over half of the current.
   (D) All of the current.

5. If current and voltage of an AC circuit pass through maximum value at the same time and in opposite directions, they are:

   (A) equal.
   (B) 90° out of phase.
   (C) in phase.
   (D) 180° out of phase.

6. In an AC circuit, the frequency of the power wave is how many times that of the voltage wave?

   (A) One-fourth.
   (B) One-half.
   (C) Twice.
   (D) Four times.

SAMPLE AC ELECTRICITY EXAMINATION (CONT.)

7. What relationship does the current and voltage have in a purely resistive AC circuit?

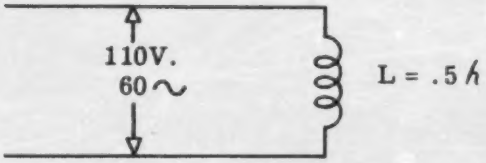
(A) The current and voltage are in phase.
(B) The current lags the voltage by 90 degrees.
(C) The current leads the voltage by 90 degrees.
(D) The current and voltage are 180 degrees out of phase.

8. In an AC circuit, true power can be found by:

(A) multiplying total voltage by total current.
(B) dividing resistance by the circuit impedance.
(C) multiplying circuit current by power factor.
(D) use of an instrument called a wattmeter.

9. The inductive reactance of the coil in the circuit shown below is:

(A) 188.5 ohms.
(B) 377 ohms.
(C) 1885 ohms.
(D) .005 ohms.



10. Which of the below statements are true concerning inductance?

(A) Inductance is equal to $2\pi fL$.
(B) Inductance is the opposition to any change in current flow.
(C) Inductance will vary with the frequency.
(D) All of the above.

11. What factors will determine the inductive time constant of a circuit?

(A) Inductance and current
(B) Inductance and voltage
(C) Inductance and frequency
(D) Inductance and resistance

12. In order to increase X_L, you should:

(A) add inductance in series.
(B) increase the number of turns in the coil.
(C) add an iron core to the coil.
(D) all of the above.

APPENDIX C

Page C-3 is a sample instruction page for use of the Self-Tutor. The operation of the mask is the same as described in Experiment IA.

Page C-4 is a sample page of the calculus program. It will be noted that there are circled numbers within the stimulus area of each frame. These numbers provide a code for the S to indicate to him that this information is to be written beside the code number in the programed notebook (Page C-5).

TABLE 21

Analysis of variance of Ability (GCT and ARI Scores Combined) (Calculus)

Source	df	ss	ms	F-ratio
Columns	1	361.35	361.35	2.23*
Within	32	5193.64	162.30	
Total	33	5554.99		

*no significant difference

The analysis indicated that there was no significant difference between the abilities of the experimental and the control groups.

TABLE 22

Analysis of Variance of Age (Calculus)

Source	df	ss	ms	F-ratio
Columns	1	503.71	503.71	14.3***
Within	32	1127.46	35.23	
Total	33	1631.17		

***significant at the .001 level

The analysis indicated that there was a significant difference between the ages of the experimental and the control groups.

TABLE 23

Analysis of Variance of Examination Scores (Calculus)

Source	df	ss	ms	F-ratio
Columns	1	1296.83	1296.83	6.86**
Within	32	6053.70	189.18	
Total	33	7350.53		

**significant at the .025 level

This analysis indicated that there was a significant difference between the examination scores of the experimental and the control groups.

Because of the significant differences obtained in the ages and examination scores of the experimental and control groups, an analysis of covariance was performed on these two sets of data. The results of this analysis are shown in Table 24.

TABLE 24

Analysis of Covariance of Age and Examination Scores Adjusted for Ages

Source	df	ss_x	sp	ss_y	ss'_y	df	$ms_{y'}$	F-ratio
Columns	1	503.71	-808.22	1296.83	1185.91	1	1185.91	5.88*
Within	32	1127.46	- 26.63	6053.70	6053.07	31	201.67	
Total	33	1631.17	-834.85	7350.53	7238.98	32		

*significant beyond the .05 level.

The results of the analysis of covariance indicate that the use of the programed text had a significant effect upon the Ss examination scores since when an adjustment is made for the differences in age the use of a programed text was superior to that of a traditional text for homework use.

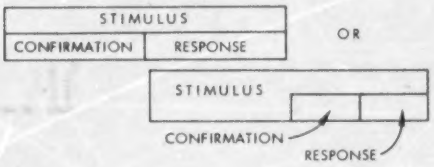
TMI-GROLIER

SELF-TUTOR

OPERATING INSTRUCTIONS

You are about to begin a new adventure in learning. These instructions tell you how to use your TMI-Grolier Self-Tutor and how to help others to use it.

1. Open the Self-Tutor to the position shown in figure 1.
2. Note that the mask (figure 1) is attached to the right side of the Self-Tutor by means of a plastic guide. By sliding the mask along this guide, the instruction frames will be visible through the window.
3. Lift the mask and fold it over to the right, exposing a slit on the left side and a strap at the top. A hidden slit holds the answer pad (figures 1 and 2). The strap holds top-bound textbooks (figure 1) and the vertical slit holds side-bound textbooks (figure 2). Insert only the back covers of the textbook into the slit or strap, in the same manner as the answer pad.
4. Turn the Rotating Flap to the appropriate window position indicated on the title page of your TMI-Grolier self-tutoring course.
5. Find frame 1 on the first page of your program and slide the mask up until the window is over that frame. Your mask should be in the position shown in figure 2. Check that the Rotating Flap is in the proper position for your program.
6. Notice that each frame is divided into three parts; stimulus, response and confirmation.



7. When your mask is properly positioned, the stimulus and response areas are exposed, and the confirmation area is covered.
8. In the stimulus space you will find information and questions. Write your answer either in the response area or on the corresponding section of the answer pad.
9. Now slide the mask down and check your answer against the correct answer in the confirmation space.
10. Slide the mask down and work the next frame in the same manner.
11. When you have completed the last frame on the page, flip the mask to the right and turn to the next page.
12. Flip the mask back to the left and move it up to the first frame on that page. Continue following the succeeding numbered frames and sections in the same manner until you come to the back of the textbook.
13. Now slide your textbook out of the Self-Tutor. Turn the textbook around and insert the front cover into the same slit or strap in the Self-Tutor. Continue working the succeeding numbered frames in the same manner until you have completed the course.

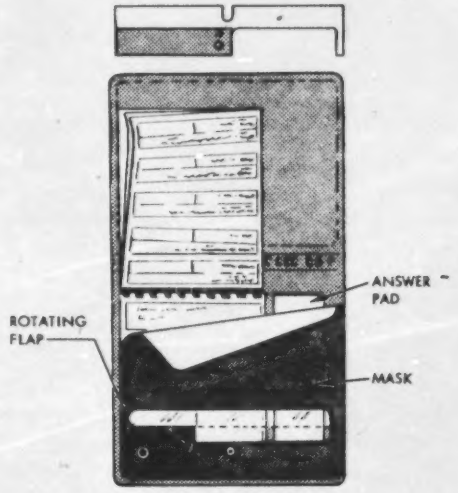


Figure 1. Rotating Flap - Window #2 Position.

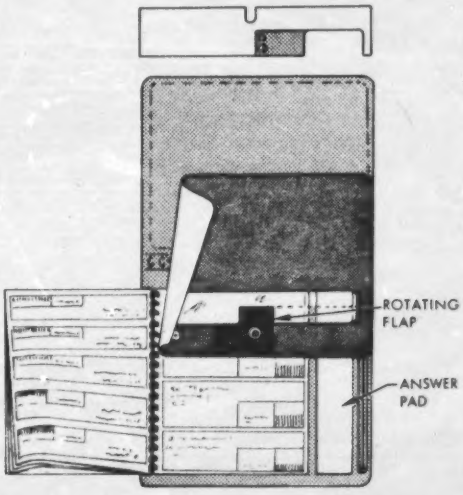


Figure 2. Rotating Flap - Window #1 Position.

1

The exponent L in the equation $b^L = N$, $b > 0$, $b \neq 1$, is defined to be the LOGARITHM of N to the BASE b. (15.1)

In $3^2 = 9$, 2 is the logarithm of 9 to the base 3. In $2^5 = 32$, 5 is the _____ of *** to the base ***.

logarithm 32 2

2

If $b^L = N$, $b > 0$, $b \neq 1$, then L is the logarithm of N to the base b. (15.2)

$b^L = N$ can also be written $L = \log_b N$. $L = \log_b N$ is read _____.

L is the logarithm of N to the base b

3

$b^L = N$ and $L = \log_b N$, $b > 0$, $b \neq 1$, say the same thing. $3^2 = 9$ and $2 = \log_3 9$ are equivalent statements. Write $4^2 = 16$ in another way. ***

$\log_2 16 = 4$

4

In this and subsequent frames, assume $b > 0$, $b \neq 1$. $b^L = N$ is called the EXPONENTIAL FORM; $L = \log_b N$ is called the LOGARITHMIC FORM. (15.3)

Express $2 = \log_5 25$ in exponential form. ***

$5^2 = 25$

5

Express $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$ in logarithmic form. ***

$\log_{\frac{1}{2}} \frac{1}{8} = 3$

30-1

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15.0 Logarithms.

15.1 The exponent L in the equation $b^L = N$, $b > 0$, $b \neq 1$, is defined to be the logarithm of N to the Base b.

15.2

15.3

15.4

15.5

15.6 Laws of Logarithms

15.61

15.62

15.63

15.64

15.65

APPENDIX D

TABLE 25

Students' Reaction to Programed Learning

		Like		Neither Like Nor Dislike		Dislike
		2	1	0	1	2
Stimulating	2	12				
	1	8	4	1	3	
Neither Stimulating Nor Boring	0	1				
	1	19	3		6	7
Boring	2					11

The above table gives an indication of the students' reaction to programed learning and teaching machines in AC and DC Electricity. Quite a few of the students thought they were fair as instructional devices but that it was slightly boring to sit and respond to a program for long periods of time.

The following comments are representative of the students' attitudes:

"To me the teaching machine has been a wonderful experience. I like it very much. It isn't the most exciting way to be taught but I think if the humor that is exemplified in the units was a little more occurant it would help a lot. I seem to have learned a lot these last two weeks and the

machine should get a lot of credit for it. I would like to say that if there was a choice between a machine and the teacher, I'd be inclined to use the machine. Another suggestion would be to have slightly more comfortable chairs on which to sit."

"I think these teaching machine is a good thing if it was use at home as a self-teaching aid. But here in school you are pressed for time and have to do a certain amount of work in a given period."

"It takes up the time of the teacher when he can be explain or demintrating things to the whole class."

"It is also monotonous and did not allow us enough time for are experiments."

"The green box is slow because of the time it takes to work it and it has too many mistakes in it but it does teach what is in it by repeating it so many times that one can't forget it. One falt is that it will not answer questions but then one doesn't have to wast time lissening to other peoples stupid questions. Another good point is that the student does not fall asleep."

The following general comments were made concerning programed learning and teaching machines in the calculus course.

Advantages: The repetitive nature of the exercise problems are excellent. Definitions of unfamiliar terms are concise. Derivation of standard formulae in the algebra, plane trigonometry and logarithm sections is easily understood by the average trainee.

Disadvantages: Derivation of standard formulae in the calculus sections is somewhat rigorous for the average trainee. Lengthy, repetitive exercises tend to develop mechanics vice understanding in problem solving and the time consumed, in relation to the time allotted for the course, is excessive.

Suggestions: The number of problem exercises and repetitive problems should be established in accordance with the difficulty level of the concept. Due to the time allotted for the course, repetitive problems must be held to an optimum minimum. A list of textbooks including chapter, page, and/or paragraph numbers from which the exercises were extracted should be provided for instructor reference. Correct, verified answers should be available for instructor reference to facilitate review.

APPENDIX E

Sample pages of the refresher mathematics program are included in this appendix. It has been previously mentioned that there was insufficient time for the pre-testing and validation of this program using Ss at the U. S. Naval Training Center.

SAMPLE REFRESHER MATHEMATICS PROGRAM

To add $\frac{7}{16}$ and $\frac{1}{4}$, find the lowest common denominator. In this case it is 16. The fraction $\frac{7}{16}$ needs no change, but to change $\frac{1}{4}$ to 16ths, multiply both numerator and denominator by 4.

$\frac{1}{4} \times \frac{4}{4} = \frac{4}{16}$ Then $\frac{7}{16} + \frac{4}{16} = (\quad)$

$\frac{11}{16}$

Perform the indicated operations:

$\frac{9}{20} + \frac{3}{8} = (\quad)$ $\frac{3}{5} + \frac{1}{6} = (\quad)$ $\frac{1}{3} + \frac{5}{8} = (\quad)$

$\frac{33}{40}$ $\frac{23}{30}$ $\frac{23}{24}$

To subtract fractions, the same procedure is followed just as in addition of fractions.

Subtract $\frac{5}{8}$ from $\frac{3}{4}$. $\frac{3}{4} - \frac{5}{8} = (\quad)$

$\frac{1}{8}$

Perform the indicated operations:

$\frac{3}{5} - \frac{1}{6} = (\quad)$ $\frac{5}{8} - \frac{1}{3} = (\quad)$

$\frac{13}{30}$ $\frac{7}{24}$

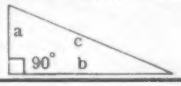
To multiply fractions, multiply the numerators together and then multiply the denominators together.

$\frac{5}{8} \times \frac{3}{4} = \frac{15}{32}$ $\frac{1}{2} \times \frac{1}{6} = (\quad)$

$\frac{1}{12}$

SAMPLE REFRESHER MATHEMATICS PROGRAM (CONT.)

A right triangle is a geometric figure in which two of the three intersecting lines are perpendicular to each other and form a right angle or an angle of 90°.



Line a is _____ to line b.

perpendicular

A right triangle is a geometric figure in which one angle formed by the three intersecting lines is a _____ angle.

right

A right angle is an angle of ( ) degrees.

90

Sketch a right triangle _____.

or any similar figure

An angle of 90° is a _____ angle.

right